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(54) Title: ENERGY EXTRACTION FROM THE INLET AIR OF AN INTERNAL COMBUSTION ENGINE

(57) Abstract

At the air intake of an internal combustion engine is provided a turbine through which airflow to the engine passes. The turbine is coupled to a shaft which is connected to a turbine within the exhaust system of the engine and through an electric motor/generator coupling to the drive shaft of the engine. The turbine can be driven by the expanding air in the air intake to cause cooling of the air and the output of power. The cooled air is used by heat exchanger to extract usable cool for the passenger compartment or other equipment. The turbine can be driven from the engine output shaft or from the exhaust turbine as a supercharger or turbo charger to compress the air for intake into the engine to increase power. The system can be controlled to provide increased engine power as required, increased fuel efficiency due to the extraction of extra energy from the expanding intake air and air conditioning without the necessity for a freon type air conditioning system.

+ DESIGNATIONS OF "SU"

Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

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ENERGY EXTRACTION FROM THE INLET AIR OF AN INTERNAL COMBUSTION ENGINE

This invention relates to an internal combustion engine of the type including a combustion chamber, movable element mounted in the combustion chamber and movable in response to combustion to provide a motive power from the engine, an air intake system, an exhaust system and a fuel injection system; and particularly to a system for extracting energy from the air flowing through the air inlet system into the chamber.

The vacuum system of an engine is well known to provide a simple source of motive power for example for motors for driving the windscreen wipers of a vehicle or for driving the power brake pump of a vehicle. These motor systems simply extract a small portion of the vacuum available and do not interact directly with the air flow into the engine.

Turbo chargers and superchargers act to engage the air flow within the intake duct and to compress the air to obtain an increased mass of air for injection into the combustion chamber for increased power.

However little attention has been given to the possibility of extraction of significant energy from the air flow.

Attempts have been made by Baumgartner (assigned to Pierburg GmbH) in U.S. Patent 4,508,089 and DE application 3313679 to utilize throttle energy by a vane type positive displacement pump/motor at the air intake which is directly mechanically connected with the engine output shaft to rotate therewith at proportional speeds. However this device has apparently achieved little success possibly due to the complexity and expense of the system and possibly due to the lack of flexibility in the system.

It is one object of the present invention, therefore, to provide an improved internal combustion engine in which energy can be utilized from the air intake system.

According to the invention, therefore, there is provided an internal combustion engine comprising a combustion chamber, a movable element mounted in the combustion chamber and movable in response to combustion to provide motive power from the engine, an air intake system including an air inlet into the chamber for controlling air flow into the combustion chamber for combustion, an exhaust system including an exhaust outlet from the chamber for controlling the emission of combustion gases from the chamber, a fuel system for supplying fuel so as to enter into the chamber including means for controlling the quantity of fuel supplied in association with

the mass of air inlet into the chamber to obtain a required level of motive power, the air intake system including an air intake duct having an inlet for drawing air from atmosphere, a throttle valve for controlling the rate of flow of air through the duct such that a predetermined volume of air flows into the duct at a pressure lower than atmospheric pressure, turbine means for physically contacting and responsive to said volume of air while flowing in said duct for extracting energy therefrom while causing cooling thereof and heat exchanger means downstream of the turbine means for extracting useable cool from the air.

Thus the energy is used in the form an expansion engine driven by the air as it expands from atmospheric pressure to the reduced pressure at the vacuum pressure of the intake line. This causes the air to cool automatically. This cool can be used by extraction via a heat exchanger to produce an air conditioning system of the vehicle within which the engine is mounted. This has the advantage that the heat exchanger causes reheating of the air so that it reaches the engine at more suitable temperature for combustion.

The energy developed in the expansion engine, which causes the cooling of the air by extracting energy from the air can be simply dissipated or can be utilized to drive a

generator, pump or the like or can be communicated to the drive output of the engine. Preferably this can be effected by a generator driven by the expansion engine which communicates power through an electric motor to the drive train.

In a further preferred arrangement, a turbine member is mounted within the air intake duct with the turbine member providing two alternative paths one of which generates an expansion of the air as it passes through the turbine member thus acting as an expansion engine and providing the cooling defined above. A second path through the turbine member is arranged to generate a compression of the air so as to act as a super or turbo charger for increased power. The combustion air turbine member can be connected to a driven turbine within the exhaust system so that the combustion air turbine can be driven when compression is required. The driven turbine can merely be used to dissipate the energy when the combustion air turbine is driven.

Heat can be extracted by the heat exchanger downstream of the turbine when acting in the turbo-charger mode and this heat can be used to provide instaneous heat to the passenger compartment. This has the advantage of immediate heat being available without waiting for the warming of engine coolant in the conventional heating system.

In a further arrangement the turbine member when driven by the expansion of the air in the intake system can be used to drive auxiliary systems of the engine for example an electrical generator or other energy extraction system.

One or more embodiments of the invention will now be described in conjunction with the accompanying drawings.

Figure 1 is a schematic illustration of a first system according to the present invention.

Figure 2 is a similar schematic illustration of a second system according to the present invention.

Figure 3 is a schematic illustration of a centrifugal type turbine arrangement for use in the system of Figure 2.

Figure 4 is a schematic illustration of an axial type turbine arrangement for use in the system of Figure 2.

In Figure 1 is shown schematically the inlet and discharge systems of a combustion engine and particular system for extraction of energy in the form of cool air from the inlet air into the engine.

The engine is generally indicated at 10 and includes one or more cylinders each having a movable element 12 within the cylinder which is moved in response to the combustion within the cylinder to provide motive power at an

output shaft 13. The details of the engine are not shown as these are well known to one skilled in the art and can be constituted by various different designs of engine for example, conventional piston engines, rotary engines and others.

An air inlet system is generally indicated at 15 for transmitting air from an inlet 16 of a filter 17 through a valve system 18 of the engine 10 into the cylinders or combustion chambers for the combustion process. An exhaust system is indicated generally at 20 and includes an exhaust duct and muffler arrangement generally indicated at 21 which receives the exhaust gases to a valve system generally indicated at 22 from the combustion chamber subsequent to the combustion process.

The conventional engine system further includes a throttle valve 25 for controlling the flow through the inlet duct 15 to the engine in response to actuation of the operator controlled throttle mechanism schematically indicated at 26. The device further includes an air/fuel ratio control device generally indicated at 27 which receives fuel from a supply 28 and controls the injection of that fuel into the air in the inlet duct for injection through the control valves 18 into the combustion chambers. The control device 27 is controlled by an electronic control module 29 conventional in fuel injected

engines and of a type well known to one skilled in the art.

The conventional engine described above is modified by the addition of a system for generating and extracting cool within the air passing to the engine. The device thus comprises a turbine member 30 located within the system 15 so that it is contacted by the air as it flows through the system. The turbine member includes a path 31 therethrough which allows expansion of the air as it passes through the path from an inlet 32 of the expansion turbine to an outlet 33 of the expansion turbine. The air as it expands thus passes wholly through and over the turbine member thus driving the turbine to provide output rotation of a shaft 34 of the turbine. The air at the inlet 32 is thus substantially at atmospheric pressure (for example 14.7 psia) as released into the system through the air filter 17 and the inlet 16. The air at the outlet 33 of the turbine is at a reduced pressure (approximately 7.0 psia) and is significantly expanded by an expansion ratio for example of the order of 1:2. In addition energy is extracted from the air by the expansion engine thus causing a temperature drop in the air between the atmospheric air temperature and a low temperature downstream of the expansion engine. In one practical example, the air temperature at atmospheric pressure will be of the order of

100°F. Subsequent to the expansion across the expansion engine, the temperature of the air flowing in the air inlet duct will be of the order of 0°F. In a typical example, the volume of air flowing will be of the order of 100 CFM at this temperature producing approximately 10,000 BTU/HR of heat removal from the manifold air.

Downstream of the outlet 33 from the expansion engine and upstream of the engine throttle valve is provided a heat exchanger 35 shown schematically which provides an air to air heat exchange arrangement transmitting heat between air recirculated from an area to be cooled and returned to that area so that the cool extracted from the air in the inlet duct is transmitted to the area to be cooled to provide cooling thereof. At the same time the air within the inlet duct is warmed so that it reaches the combustion chamber at a temperature more suitable for combustion.

The electronic control module is arranged to control as previously described the injection of fuel into the air stream. In addition the electronic control module is arranged to control a bypass valve 36 which allows the air flow to bypass the expansion engine and the heat exchanger either when no cooling is required or when the demand for power from the engine actuated by the throttle control valve 26 is such

that the resistance to flow of the air within the inlet duct cannot be accomodated and full flow of air is required.

Turning now to Figure 2 there is shown an arrangement similar to Figure 1 including a combustion engine 10 having an air inlet system 40 and an exhaust system 41. In this case the engine includes for each separate cylinder a fuel injection device 42 each controlled by an electronic control module 43. Each fuel injection device receives air from the inlet system 40 and fuel from a suitable supply (not shown) for injection into the separate cylinder of the engine which is respectively associated with the fuel injection device.

In this arrangement therefore the control module 43 can be arranged to control the fuel and air supply to each of the cylinders individually, so that the fuel to one or more of the cylinders can be halted and the air control valve opened. In this situation the cylinder is acting as an air pump so the airflow (40) is maintained at a relatively high value. Thus the relatively high air flow can be used as explained previously for extraction of energy from the air flow. Even at idle, therefore, sufficient cool can be extracted from the air to provide cooling to a part of the vehicle within which the device is mounted.

The air inlet system 40 in this case includes an

expansion engine or turbine indicated at 45 which has two paths indicated at A and B respectively through the expansion engine. The path A is arranged so that the air enters the larger volume section of the turbine and moves to the lower volume section of the turbine so that the air is compressed as it passes through the turbine. In this case in order to achieve the compression action energy must be introduced into the turbine 45 and this is provided either by a turbine 46 mounted on a shaft 45A within the exhaust system 41 or by an electric motor/generator indicated at 46A coupled to a symmetrical motor/generator on the output shaft 101 of the engine. This acts therefore as a supercharger. In this mode, therefore, the turbine 45 acts as a substantially conventional turbo charger extracting energy from the exhaust system and applying it to compress inlet air leading to the combustion chambers to increase the amount of fuel which can be introduced and thus extract greater power from the combustion action.

In the second path B, the air passes from the smaller volume section of the turbine 45 to the higher volume section thus expanding the air in the manner explained previously, extracting energy therefrom and providing a significant degree of cooling of the air.

A third path C is provided as a system bypass so

that the air can completely by pass the turbine and pass directly to the fuel injection devices 42. The selection of the path A, B or C is in the control of a valve arrangement 47 controlled by the electronic control module 43 of the engine. This selection is made depending upon the amount of power demanded from the engine as selected by the driver through the engine throttle control valve and also any requirement for cooling or heating (described later).

An accessory drive system indicated at 48 driven by one of the turbines 45 and 46 depending upon the mode selected. The accessory driven can be an alternator. The fact that the alternator is not driven continuously can be accomodated by backup power from a suitable battery source. Downstream of the turbine 45 is provided a pressure relief valve 50 for releasing excess pressure if required.

Downstream of the pressure relief valve is provided an atmospheric water condensate drain pump indicated at 51. This acts to extract condensate from the air which forms by condensation as the air is significantly cooled thus reducing the temperature of the air below the dewpoint. Freezing of the atmospheric moisture in the expansion engine can be avoided by three techniques. Firstly quick change valving can be provided to operate the expansion engine as a

compressor for a short period to melt out any ice forming within the expansion engine. During the defrost part of the cycle, the heated air thus obtained can be dumped to atmosphere.

Secondly a heating coil can be installed before the expansion engine to preheat the air for short periods of time again in a defrost cycle to melt out the ice thus allowing the expansion engine to continue in the cooling mode when required.

Thirdly the expansion engine can be constructed with multiple stages of expansion and interstage combustion air to air heat exchangers 52 so the coldest temperature of the combustion air is never less than 32^{o}F. Full expansion and thus energy and cool extraction are thus maintained.

The air to air heat exchanger in this embodiment is indicated at 52 and in this case can act either to provide warm air during the compression cycle or path A of the turbine 45 or can be used to provide cool air during the expansion mode or path B of the device. In the warm air mode, heating can be available immediately, to avoid delay as in engine coolant type passenger heating system. In the situation where neither warm air nor cooled air is required, the heat or cool thus obtained can be dumped to atmosphere or the system will be bypassed via

route C.

Downstream of the heat exchanger 52 is provided a further heat exchanger 53 which in this case is a liquid to air heat exchanger for extracting heat from the engine coolant in a situation where warming of the combustion air is required before injection into the engine for the combustion process. The heat exchanger 52 can also be of the air-to-air type where ambient air is the heat source.

A battery source is indicated at 46C for providing power to the shaft 45A when no power is available from the output shaft 101 or from the turbine 46.

Figures 3 and 4 show in more detail two alternative constructions of the turbine 45 which provides the two paths A and B.

In Figure 3 is shown an arrangement including a centrifugal turbine 45A which has first and second alternate inlets 45B, 45C. In the expansion or cooling mode valves A and D are opened and valves B and C are closed so that air enters the inlet 45C and exits at 45B. In the compression or heating mode, valves B and C are opened and valves A and D are closed so that air enters the inlet 45B and exits at 45C. In Figure 4, the same arrangement is illustrated in conjunction with an axial type turbine.

The following modes of operation of the system as shown in Figure 2 can be utilized as required.

1. Electric Supercharger

Operating Mode - system for passenger compartment heating and increased engine power;

Energy Moved From - Auto Battery or electrical alternator;

Energy Moved To - Intake manifold charger and to passenger compartment or other area requiring heating if required;

Energy Movement Method/Route - Battery to Electric wires to electric charger motor to charger impeller to airflow in intake manifold;

Effect:

a) More airflow in intake manifold

b) rate of energy drawn from battery will be high but will last for a short period of time only with sporadic turbo-charger use;

Benefits:

a) Supercharger can be brought up to full speed before engine actually needs the air therefore more air is immediately available when a high amount of internal combusion engine power is required.

2. Mechanical Driveshaft powered Supercharger

Operating Mode - used to heat passenger compartment only.

Energy Moved From - Internal Combustion engine driveshaft;

Energy Moved To - Supercharger and to heating/cooling coil where passenger air is heated;

Energy Movement Method/Route - Internal combustion engine driveshaft to supercharger heating/cooling coil to passenger compartment of automobile;

Benefit - Instant supply of warm air to passenger compartment.

3. Turbo charger system for passenger compartment heating.

Operating Mode - using heat from turbo charger air to heat passenger compartment.

Energy moved From - exhaust gas manifold;

Energy moved To - heating/cooling coil that heats the passenger compartment or other area requiring heat;

Energy Movement Method/Route -

a) from turbo to charger (intake manifold);

b) intake manifold charger compresses air;

c) compressed air is cooled via air to air heat exchanger (called intercooler);

d) heat leaves intercooler and goes to passenger compartment via passage compartment air heating system;

Effect - Instant supply of heated air to passenger compartment. The charger can operate until the engine coolant heating system becomes warm enough to heat the car.

Benefits -

a) Instant heating of auto passenger compartment or other area requiring heating in cold weather.

b) Prevention or removal of window fogging mist when car is driven in cold weather before the engine coolant is warm.

4. Expansion Engine System

Operating Mode - For providing cooling effect to auto passenger compartment or other areas requiring cooling or air conditioning for example a transport truck trailer;

Energy Moved From - intake manifold air;

Energy Moved To - Options

a) wasted to atmosphere by energy dissipation device i.e. "a fan";

b) electric generator on expansion turbo engine shaft which can;

i) charge battery

ii) provide power to other electrical devices one of which can be an electric motor providing power to the combustion engine drive shaft;

iii) dissipate energy (waste) to turbo impeller inside exhaust gas manifold, i.e. energy flow is opposite of that when turbocharging;

Energy Movement Method/Route - Expansion of air accompanied by work extraction removes heat from intake manifold air producing cold air in the intake manifold. This cold air removes heat from the passenger compartment recirculating air via an air to air heat exchanger. This removal of heat warms the combustion air. Additional heat is supplied by the engine coolant to combustion air heat exchanger to provide the combustion air at desired temperatures.

Benefit - By use of an electric motor/generator to electric motor/generator system, one at the charger and one at the internal combustion engine driveshaft power can be moved as required to move energy from the turbo (expansion engine) to the internal combustion engine driveshaft to provide additional driveshaft power. The removal of energy from the turbo expansion engine cools the combustion air which via an air to air heat exchange cools the passenger compartment. The energy removed by the expansion engine is replaced by the air conditioning system and/or the engine coolant such that all the expansion motor energy is free, that is, attained from the engine coolant which would be dissipated to atmosphere as radiator heat. The additional energy produced by the electric motor/generator at the engine crankshaft is also free and therefore can increase the power or fuel economy of the

internal combustion engine.

Expansion Engine System

Benefit - The use of a motor/generator system allows computer control of the mechanical system for better flexibility and optimigration of the system vs a mechanical connection between the expansion engine and internal combustion motor which will be slower to respond to system charges and have higher mechanical inertia.

-The computer would take information input from engine sensors, throttle position, etc. and control the motor/generator as required for optimization of power, fuel economy, automobile heating/air conditioning, etc..

CLAIMS:

(1) An internal combustion engine comprising a combustion chamber, a movable element mounted in the combustion chamber and movable in response to combustion to provide motive power from the engine, an air intake system including an air inlet into the chamber for controlling air flow into the combustion chamber for combustion, an exhaust system including an exhaust outlet from the chamber for controlling the emission of combustion gases from the chamber, a fuel system for supplying fuel so as to enter the chamber including means for controlling the quantity of fuel supplied in association with the volume of air inlet into the chamber to obtain a required level of motive power, the air intake system including an air intake duct having an inlet for drawing air from atmosphere, a throttle valve for controlling the rate of flow of air through the duct such that a predetermined volume of air flows into the duct at a pressure lower than atmospheric pressure, turbine means physically contacting and responsive to said volume of air while flowing in said duct for extracting energy therefrom while causing cooling thereof and heat exchanger means downstream of the turbine means for extracting useable cool from the air.

(2) An engine according to Claim 1 for mounting

within a vehicle and including means for transmitting the cool from said heat exchanger means to a portion of the vehicle for cooling thereof.

(3) An engine according to Claim 1 wherein the expansion engine means is rotatably driven by the expansion of the air and including means for utilizing the rotation of the expansion engine means for extracting energy therefrom.

(4) An engine according to Claim 1 including means for controlling the quantity of fuel supplied relative to the volume of air inlet such that the volume of air inlet is maintained at a high volume when said quantity of fuel supplied is reduced so as to maintain the flow of air through said duct at a high level when said engine is in idling condition.

(5) An engine according to Claim 4 including a plurality of chambers, means for injecting fuel to one or more of said chambers independently of the others of said chambers and means for halting fuel supply to one or more of said chambers while maintaining a high volume of air flow into said chambers.

(6) An engine according to Claim 1 wherein said turbine means includes a first path therethrough for causing expansion of the air and a second path therethrough for

causing compression of the air.

(7) An engine according to Claim 1 including means for providing power to and receiving power from the turbine means comprising an exhaust turbine mounted in said exhaust system.

(8) An engine according to Claim 1 including means for communicating power to and receiving power from the turbine means comprising an electric motor/generator connected to said turbine means.

(9) An engine according to Claim 1 including second heat exchanger means for exchanging heat between said inlet air and an engine coolant system of the engine.

(10) An engine according to Claim 1 including bypass means for bypassing the air flow around said means responsive to the airflow and means for controlling said bypass means in response to demand for power from said engine.

(11) An engine according to Claim 1 for mounting within a vehicle and including means for transmitting heat from the heat exchanger means in the compression mode and cool from the heat exchanger means in the expansion mode to the interior of the vehicle.

(12) An engine according to Claim 1 including means for communicating power to and receiving power from the

internal combustion engine driveshaft comprising an electric motor/generator connected to said internal combustion engine shaft.

(13) An engine according to Claim 1 including sensors and computer means to optimize the transfer of energy in the system as desired for driver comfort (passenger compartment heating and cooling) and internal combustion engine power and fuel economy.

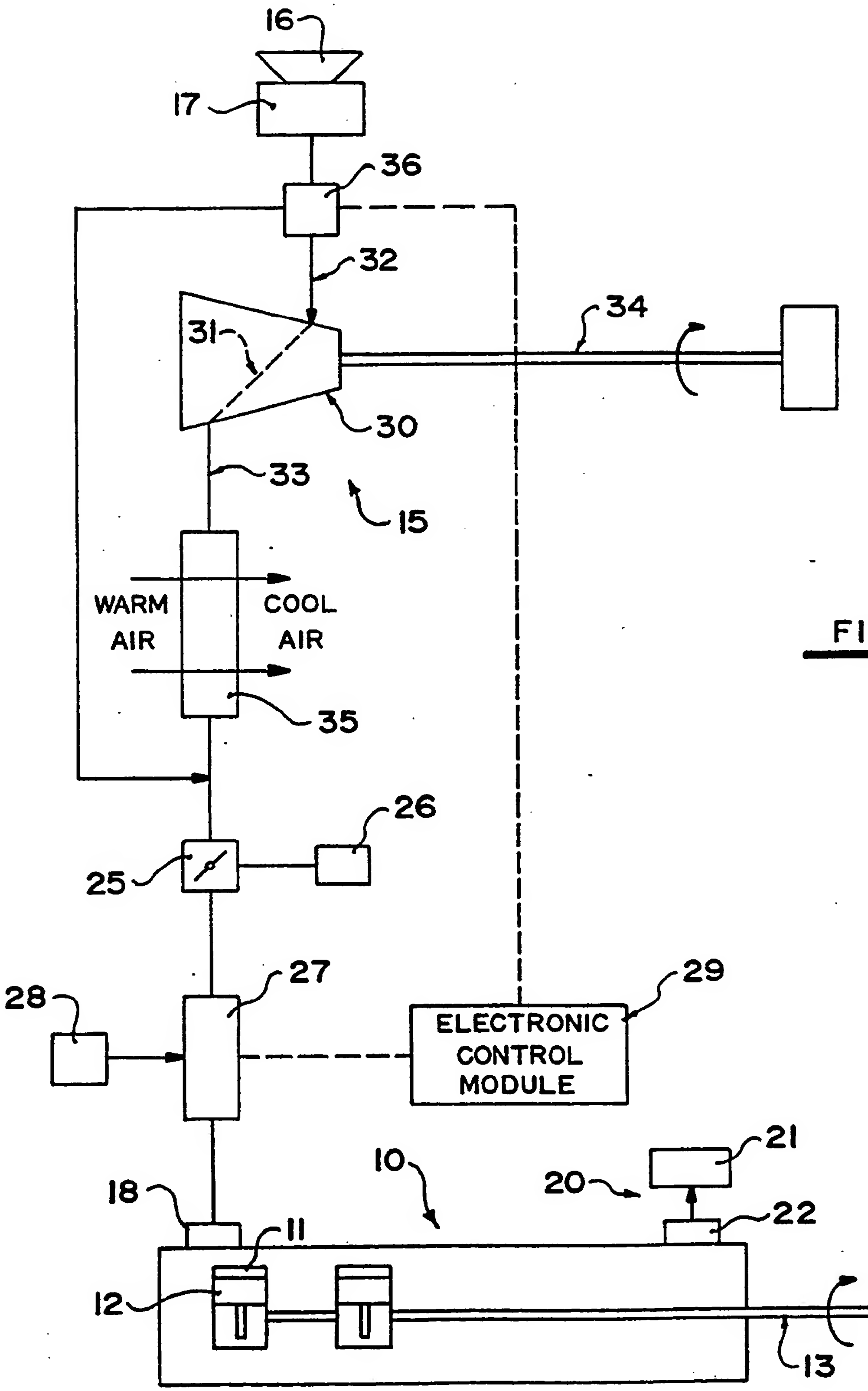
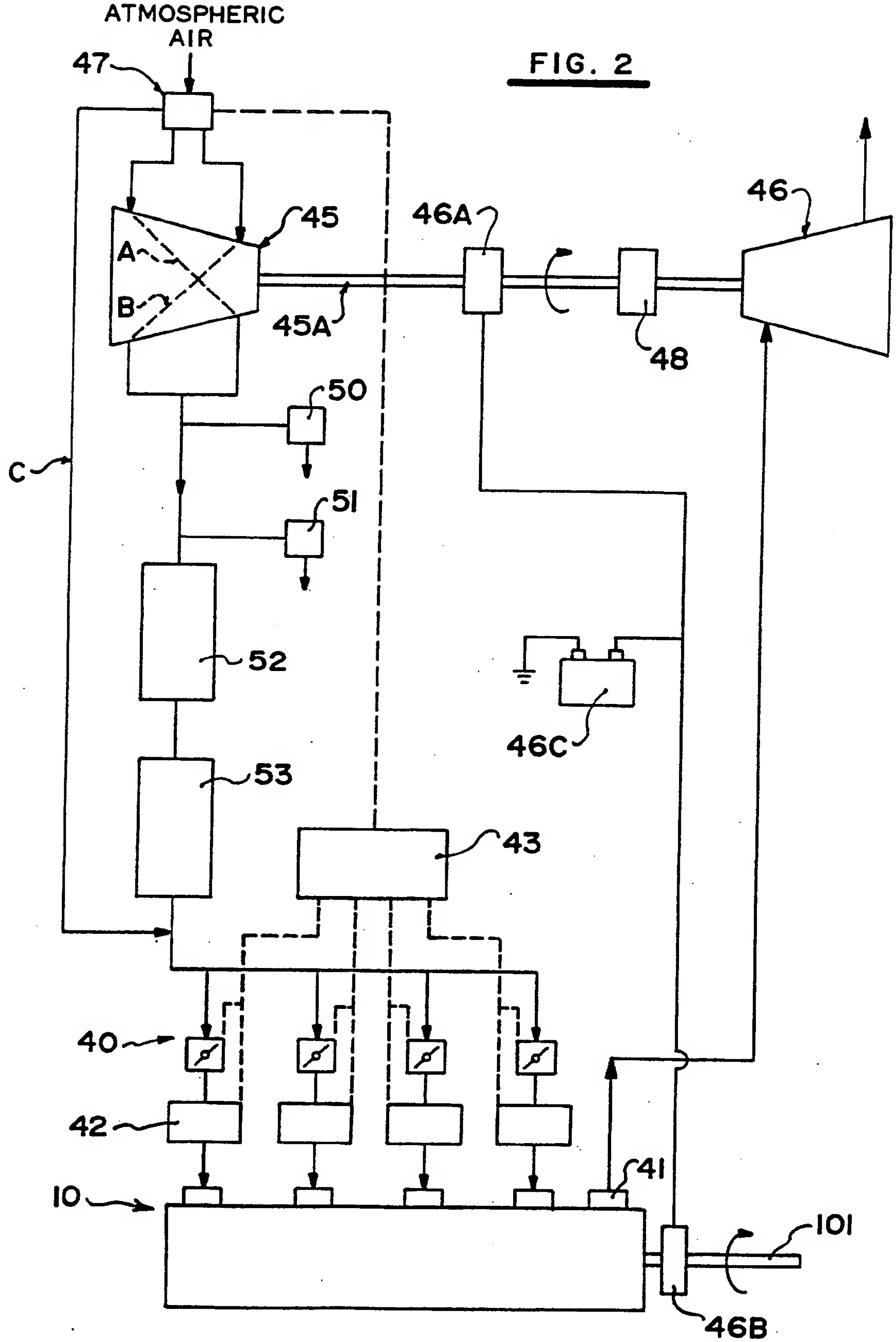


FIG. 1

SUBSTITUTE SHEET

FIG. 2


ATMOSPHERIC AIR
47
45
A
B
45A
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46
48
50
51
C
52
53
43
46C
40
42
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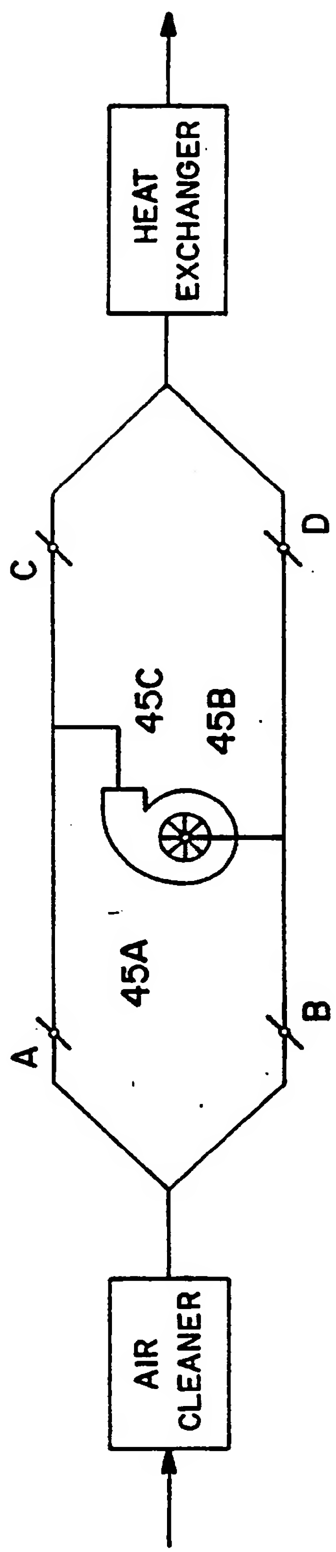
41
101
46B


HEAT EXCHANGER
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D
45C
45B
45A
A
B
AIR CLEANER

FIG. 3

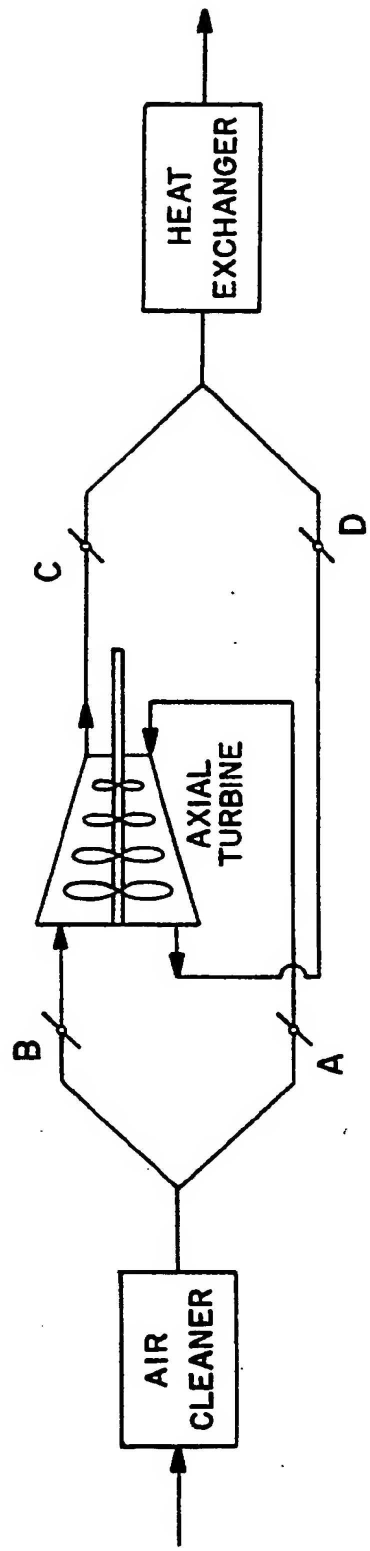
HEAT EXCHANGER
C
D
AXIAL TURBINE
B
A
AIR CLEANER

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/CA 91/00423

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 F02D9/02

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	F02D ; F02B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	GB,A,2 154 280 (ARMSTRONG WHITWORTH & CO LTD) 4 September 1985 see abstract; figure 1 ---	1,2,9, 10,11,13
X	DE,A,3 819 646 (VOLKSWAGEN AG) 29 December 1988 see the whole document ---	1,3,6,7
A	US,A,4 489 695 (NIPPON SOKEN INC) 25 December 1984 see abstract; figure 3 ---	4,5
A	EP,A,0 147 740 (CORINT SRL) 10 July 1985 see abstract; figure 2 ---	1,4

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
06 FEBRUARY 1992	13. 02 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	WASSENAAR G.C.C. GCCWassenaar

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. CA 9100423 SA 53597

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 06/02/92
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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DE-A-3819646	29-12-88	None	
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EP-A-0147740	10-07-85	JP-A- 60169635	03-09-85

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